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(54) Title: HAND-HELD OPTICAL DISC PLAYER/RECORDER

(57) Abstract: A hand-held optical disc apparatus is configured to playback/record digital audio data and store digital data. The hand-held optical disc apparatus includes a reading module, a decoder, a digital-to-analog converter, an analog output, an encoder, a recording module and a mechanism, adapted to receive an optical disc having a maximum dimension less than 100 mm. The reading module is configured to read the first compressed digital audio data from the optical disc received within the mechanism. The decoder is configured to decode the first compressed digital audio data and generate at least a portion of the first uncompressed digital audio data. The digital-to-analog converter is configured to convert the first uncompressed digital audio data from the decoder to a first analog signal. The analog output is configured to receive the first analog signal. The encoder is configured to receive second uncompressed digital audio data and generate second compressed digital audio data from at least a portion of the second uncompressed digital audio data. The recording module is configured to store the second compressed digital audio data on the optical disc.

HAND-HELD OPTICAL DISC PLAYER/RECORDER

FIELD OF THE INVENTION

The invention relates to a hand-held optical disc apparatus configured to store digital data and playback/record digital audio data on an optical disc.

BACKGROUND

Optical discs have many advantages over magnetic disks. For example, the optical disc has higher recording density and shorter access time than the magnetic disk. Reading/recording of data on an optical disc occurs without physical contact between a laser reading head and the optical disc, thus eliminating wear of the reading device and disc itself. Also, the optical disc is more generally durable than the magnetic storage medium. Therefore, the optical disc has achieved increased popularity in recent years for a wide range of applications including digital audio data storage. One type of optical disc commonly used for digital audio data storage is the Compact Disc (CD). Audio CDs are played, for example, on a CD player, a popular audio entertainment device.

SUMMARY

In a general aspect of the invention, a hand-held optical disc apparatus includes a reading module, a decoder, a digital-to-analog converter, an analog output, an encoder, a recording module and a mechanism adapted to receive a CD having a maximum dimension less than 100 mm. The reading module is configured to read first compressed digital audio data from the CD received within the mechanism. The decoder is configured to decode the first compressed digital audio data and generate at least a portion of the first uncompressed digital audio data. The digital-to-analog converter is configured to convert the first uncompressed digital audio data from the decoder to a first analog signal. The analog output is configured to receive the first analog signal. The encoder is configured to receive second uncompressed digital audio data and generate second compressed digital audio data from at least a portion

of the second uncompressed digital audio data. The recording module is configured to store the second compressed digital audio data on the CD.

In another aspect of the invention, the hand-held optical disc apparatus includes a reading module, a recording module, and a mechanism adapted to receive a DVD having a maximum dimension less than 100mm. The reading module is configured to read first compressed digital audio data stored on the DVD. The recording module is configured to store second compressed digital audio data to the DVD. The hand-held optical disc apparatus includes all the other features of the aspect mentioned above.

Embodiments of these aspects of the invention may include one or more of the following features.

The hand-held optical disc apparatus may include an audio speaker connected to the analog output. The hand-held optical disc apparatus may further include a first digital output configured for connection with an input port of a computer. The first digital output is adapted to receive data either from the reading module or from the decoder. The first digital output may be configured for connection with a serial port of the computer. The hand-held optical disc apparatus may further include a second digital output configured for connection with a parallel port of the computer. The hand-held apparatus may further include a third digital output which complies with S/PDIF (Sony/Philips Digital Interface Format).

The decoder may be configured to decode the compressed digital audio data having a format selected from a group consisting of MP3, PASC, ATRAC, DTS, AAC, AC-3, ePAC and VQF. The CD or DVD may store the first uncompressed digital audio data. The reading module may be configured to read the first uncompressed digital audio data stored on the CD or DVD. The digital-to-analog converter may be configured to convert the first uncompressed digital audio data from the reading module. The CD or DVD may have a center hole having a diameter in a range of 12 mm to 18 mm. The reading module may include a flash memory module configured to buffer and manipulate data read from the CD or DVD. The reading module may include a de-modulator configured to de-modulate data stored on the CD or DVD, a de-interleaver configured to de-interleave data stored on the CD or DVD and a channel decoder configured to perform error correction on data stored on the CD or DVD. The first compressed digital audio data and the first uncompressed

digital audio data stored in the CD or DVD may include SCMS (Serial Copy Management System) subcode information and/or watermark information. And the reading module may include a security module configured to process the SCMS subcode information and a watermark module configured to process the watermark information. Also, the CD complies with Orange Book CD standard.

The hand-held optical disc apparatus may further include an analog input and an analog-to-digital converter. The analog input is configured to receive a second analog signal. The analog-to-digital converter is configured to convert the second analog signal to the second uncompressed digital audio data. The hand-held optical disc apparatus may further include a microphone connected to the analog input. The hand-held optical disc apparatus may further include a first digital input configured for connection with an output port of a computer. The first digital input is adapted to receive data from the first output port of the computer and to transmit the data either to the recording module or to the encoder. The first digital input may be configured for connection with a serial port of the computer. The hand-held optical disc apparatus may further include a second digital input configured for connection with a parallel port of the computer. The hand-held optical disc apparatus may further include a third digital input which complies with S/PDIF (Sony/Philips Digital Interface Format).

The recording module may be configured to receive a portion of the second uncompressed digital audio data and store the second uncompressed digital audio data on the CD or DVD. The encoder is configured to generate the second compressed digital audio data having a format selected from a group consisting of MP3, PASC, ATRAC, DTS, AAC, AC-3, ePAC and VQF. The recording device may include a channel encoder, an interleaver and a modulator. The channel encoder is configured to add error correction information to data to be stored on the CD or DVD. The interleaver is configured to interleave data to be stored on the CD or DVD. The modulator is configured to modulate data to be stored on the CD or DVD. The recording device may further include a flash memory module configured to buffer and manipulate data to be stored on the CD or DVD. The recording device may further include a security module and a watermark module. The security module is configured to embed SCMS subcode information to data to be stored on the CD or

DVD. The watermark module is configured to embed watermark information within the data to be stored on the CD or DVD.

Although the CD and the DVD both have maximum a dimension less than 100 mm, they are both suitable for high volume storage of digital data. Standard-compatible digital audio compression techniques reduce the storage requirement of digital audio data and still maintain the capability to reproduce high quality audio. With the use of CD/DVD and digital audio compression techniques, the invention allows high quality digital audio to be reproduced from or recorded on a relatively small light-weight hand-held apparatus.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

FIG. 1 is a perspective view of a hand-held apparatus in accordance with the present invention for receiving an optical disc.

FIG. 2 is a perspective view of the hand-held apparatus of FIG. 1 in an open condition for receiving the optical disc.

FIG. 3 is a perspective bottom view of the hand-held apparatus of FIG. 1.

FIG. 4A is a front view of the hand-held apparatus of FIG. 1.

FIG. 4B is a rear view of the hand-held apparatus of FIG. 1.

FIG. 4C is a side view of the hand-held apparatus of FIG. 1.

FIG. 4D is an opposite side view of the hand-held apparatus of FIG. 1.

FIG. 5 is a flow chart showing optical disc recording procedures.

FIG. 6 is a flow chart showing optical disc reading and/or playback procedures.

Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

Structure

Referring to FIGs. 1 and 2, a portable, hand-held optical disc unit 10 for playback or recording of digital audio data stored on an optical disc 20 is shown.

Disc unit 10 includes a housing 30 and a mechanism 40 configured to receive optical disc 20 having an overall diameter of 80 mm and a center hole 50 having a diameter of 15 mm.

Disc unit 10 can receive optical discs 20 having a wide variety of formats including a standard 80 mm CD as well as CD Recordable (CD-R) or CD Rewritable (CD-RW). The standard 80 mm CD, also known as CD Single (CDS), has a storage capacity of 180 MB. A CDS can store 21 minutes of uncompressed digital audio data recorded with 16-bit linear PCM (Pulse Code Modulation) at a sampling frequency of 44.1 kHz. The CDS can store greater amounts of audio content if audio compression techniques are used to record the content. For example, MP3, short for MPEG-1 Layer 3, is an audio compression technology that allows near-CD quality audio to be stored in small files for quick transfer and easy storage. For example, 12:1 MP3 compression allows for 252 minutes of MP3 audio to be stored on a CDS.

Receiving mechanism 40 includes a lid 70 which covers a receiving tray 80 and a switch 60 for opening the lid. Receiving tray 80 includes a hub 90 which extends upwardly from the center of receiving tray 80 to receive center hole 50 of optical disc 20.

Referring to FIG. 3, hand-held disc unit 10 further includes a battery receiving chamber 110 on the underside of disk unit 10 that houses a battery, and a covering plate 115 covering the chamber. During operation, disc unit 10 receives DC power either from the battery loaded in battery receiving mechanism 110 or from an external power source via a DC power input 190 (FIG. 4D).

Referring to FIG. 4A, the front end of hand-held apparatus 10 includes a format switch 120 for selecting one of these compression formats: CD, MP3 and PASC. CD format represents uncompressed audio data. The uncompressed audio data is obtained from sampling a waveform, preferably with 16-bit linear PCM at a sampling frequency of 44.1 kHz. PASC (Precision Adaptive Sub-band Coding) is another audio compression technology for reproducing true CD-quality audio data. During playback, selecting MP3 causes disc unit 10 to play MP3 compressed audio data stored on optical disc 20. During recording, selecting MP3 allows disc unit 10 to record audio data in MP3 compressed format onto optical disc 20. In the same manner, selecting PASC or CD allows disc unit 10 to play or record audio in PASC or

CD format. In one embodiment, selecting CD also allows optical disc unit 10 to store or read out other types of digital data.

Referring to FIG. 4B, the rear side of hand-held disc unit 10 includes a parallel port 130, a serial USB (Universal Serial Bus) port 140 and a serial FireWire port 145. Parallel port 130 provides a parallel input/output connection with a parallel port of a computer. When connected with the computer via parallel port 130, disc unit 10 can transmit and receive digital audio data to and from the computer. Parallel port 130 uses a 25-pin connector (type DB-25) and is used to connect with a computer and other device that need relatively high bandwidth.

In a similar manner, USB port 140 provides a serial input/output connection with a serial port of a computer. Thus, hand-held disc unit 10 can also transmit and receive digital audio data to and from the computer via USB port 140. USB port 140 supports data transfer rates of 12 Mbps. FireWire port 145, defined by IEEE standard 1394-1995, is a cross-platform implementation of the high-speed serial data bus that can move large amounts of data between disc unit 10 and a computer. The standard features simplified cabling, hot swapping, and transfer speeds of up to 400 Mbps.

Referring to FIG. 4C, one side of hand-held disc unit 10 includes a digital/mic/line input 170, an analog output 175, a volume switch 150, a recording level switch 160 and a recoding mode switch 165. Digital/mic/line input 170 complies with S/PDIF format (Sony/Philips Digital Interface Format), often seen as coaxial RCA type of connector or Toslink optical connector. Digital/mic/line input 170 allows disc unit 10 to receive digital data from a digital data source such as a computer or a CD player with a digital output. The digital data can be compressed audio, uncompressed audio in 16-bit linear PCM format, or other types of digital data. Digital/mic/line input 170 also allows disc unit 10 to receive an analog signal when connected to a microphone. Analog output 175 allows disc unit 10 to transmit an analog signal to an analog device such as a headphone. Volume switch 150 allows the user to adjust sound volume during playback. Recording level switch 160 allows user to adjust the recording level. Recording mode switch 165 allows the user to record sound in either manual or automatic mode.

Referring to FIG. 4D, the opposite side of hand-held disc unit 10 includes a digital output 180 and a DC power input 190. Digital output 180 complies with the S/PDIF format and allows disc unit 10 to transmit digital data stored on optical disc

20 to a digital data storage device. The digital data can be compressed audio, uncompressed audio in 16-bit linear PCM format, or other types of digital data.

To record data, disc unit 10 includes a variety of inputs 130, 140, 145 and 170, a pair of encoders 220 and 230, a modulator 240, and a laser writing module 250. The first encoder is an audio encoder 220 which compresses audio data. The second encoder is an interleaving/concealment/error correction encoder 230 which provides error protection capability to the data to be stored. The modulator 240 converts the data to a format suitable for optical disc storage. For retrieving data, disc unit 10 includes a laser reading module 300, a demodulator 310, a pair of decoders 320 and 330, and a variety of outputs 130, 140, 145, 175, and 180. The demodulator and decoders provide reverse operations on the stored data corresponding to the modulator and encoders, respectively.

Operation

Referring to FIG. 5, to record digital audio data on optical disc 20, a number of steps are required. Incoming audio data can be in either analog or digital format. A microphone connected to digital/mic/line input 170 receives sound and converts the sound into an analog signal. An A/D (Analog-to-Digital) converter 200 connected to digital/mic/line input 170 receives and transforms the analog signal into an uncompressed digital signal (16-bit PCM linear format at a sampling frequency of 44.1 kHz). Digital/mic/line input 170 can also directly receive uncompressed digital audio data.

Alternatively, a computer can be used to provide uncompressed digital audio data to hand-held disc unit 10 via a computer input 210 such as parallel port 130, USB port 140 or FireWire port 145. Both digital/mic/line input 170 and computer input 210 are configured to receive other types of digital data including compressed digital audio data.

Encoder 230 receives compressed or uncompressed digital audio data according to format switch 120. When format switch 120 is in the "MP3" position, the uncompressed digital audio data passes to audio encoder 220 where the data is encoded in MP3 format. Similarly, audio encoder 220 encodes the uncompressed digital audio in PASC format if format switch 120 is in the "PASC" position. Next, audio encoder 220 sends the compressed digital audio signal either in MP3 or PASC

format to encoder 230 for further processing. On the other hand, selecting "CD" allows disc unit 10 to send the uncompressed digital audio data directly to encoder 230. Hand-held disc unit 10 can also receive other types of digital data and forward to encoder 230 for recording the received digital data on optical disc 20. Encoder 230 interleaves, and provides error concealment and error correction.

Detailed procedures are discussed for a sound recording in CD format in the following. In one embodiment, SCMS (Serial Copy Management System) subcode and watermark information are embedded to the digital data for security before recording.

For a sound recording in CD format, hand-held disc unit 10 receives an audio signal from a microphone connected to digital/mic/line input 170. A/D converter 200 digitizes a sample of incoming audio signal in time into two 16-bit words, one for the left channel and one for the right channel. For example, a single sample of the musical signal might be: L1 = 0111 0000 1010 1000 and R1 = 1100 0111 1010 1000. Six samples (six of the left channel and six of the right for a total of twelve) form a frame: L1, R1, L2, R2, L3, R3, L4, R4, L5, R5, L6, and R6. Encoder 230 rearranges the frame in the form of 8-bit words. Each 16-bit audio sample turns into two 8-bit words, that is: L1, L1, R1, R1, L2, L2, R2, R2, L3, L3, R3, R3, L4, L4, R4, R4, L5, L5, R5, R5, L6, L6, R6, and R6. This gives a total number of 24 8-bit words.

Then, the even 8-bit words are delayed by two blocks and the resulting words are scrambled. This delay and scramble is the first part of the interleaving process. Interleaving is an effective method for correction of error bursts. When an error burst occurs on an interleaved sequence, the location of errors look random and are distributed over many code words rather than a few code words. In the way, the number of errors that occur in each code block are low and can be corrected by using a random-error-correcting code. The resulting 24 byte frame (note that some 8-bit words in this frame are from blocks two blocks behind) adds 4 bytes of parity check information. This particular parity check information is called "Q" parity and is added based on an error correction code. The resulting 24 + 4Q = 28 byte frame is interleaved again. Each of the 28 bytes is delayed by a different period. Each period is an integral multiple of 4 blocks. Therefore, the first byte might be delayed by 4 blocks, the second by 8 blocks, the third by 12 blocks and so on. The interleaving spreads the sequence over a total of 28 x 4 = 112 blocks.

The resulting 28 byte frame is again subjected to a parity operation. This generates four additional parity bytes called P bytes which are placed at the end of the 28 byte frame. Thus, the frame has a total of 28 + 4 = 32 bytes. Finally, another odd-even delay by a single block is performed. Both the P and Q parity bits are inverted (turning the "1s" into "0s") to assist data readout during playback. An 8-bit subcode is then added to the front end of the frame. The subcode specifies additional information such as the total number of selections on the disc, their length, and so on.

Next, the 8-bit data words are converted by EFM (Eight to Fourteen Modulation) modulator 240 into EFM format. EFM minimizes the number of 0 to 1 and 1 to 0 transitions so that the resulting data words are suitable for storing on optical disc 20. In EFM, only those combinations of bits are used in which more than two but less than 10 zeros appear continuously. For example, a decimal number 10 (0000 1010 in binary) is an EFM 1001 0001 0000 00.

Each frame further has a 24-bit synchronization word (100000000001000000000010) attached to the front end of the frame. Each EFM modulated word is then coupled by three merge bits. These merge bits are chosen so that there is no adjacent 1's from neighboring EFM words and the average number of "0's" and "1's" is about the same. Thus, the final frame (which originally included at 6*16*2 = 192 data bits) now contains 588 bits including: 1 sync word (24 bits), 1 subcode signal (14 bits), 6*2*2*14 data bits (336 bits), 8*14 parity bits (112 bits), 34*3 merge bits (102 bits). EFM modulator 240 forwards the final frame to laser writing module 250. Laser writing module 250 records the final frame on optical disc 20. In one embodiment, laser writing module 250 includes a flash memory module adapted to buffer and manipulate data to be stored on optical disc 20.

Referring to FIG. 6, playback or reading out of the digital data stored in optical disc 20 causes the digital data to flow in a reverse direction of recording. A laser reading module 300 reads data stored on optical disc 20. In one embodiment, laser reading module 300 includes a flash memory module to buffer and manipulate the data. When the laser within laser reading module 300 skips reading due to a disturbance on disc unit 10, the flash memory buffer provides the data for continuous playback. The flash memory also allows the data to be manipulated, for example, to change the order of the audio to be played. An EFM demodulator 310 and an interleaving/concealment/error correction decoder 320 decode the data. In one

embodiment, SCMS subcode and watermark information are processed if they are embedded in the digital data to be read out.

An MP3/PASC decoder 330 decompresses the data if it is compressed in either MP3 or PASC format. The uncompressed data might be converted to an analog signal by a D/A (Digital-to-Analog) converter. The uncompressed data might also be read out by a computer 350 via parallel port 130, USB port 140 or FireWire port 145. It can also be read out by other devices via a digital output 180.

A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention.

For example, optical disc 20 can also be a Digital Versatile Disc (DVD) including DVD Recordable (DVD-R) or DVD Rewritable (DVD-RW and DVD-RAM) discs. The standard single-side single-layer 80mm DVD has storage capacity of 1.4GB, which is enough to store 159 minutes of uncompressed digital audio data recorded with 16-bit linear PCM. Therefore, it can store as much as 10 hours of CD quality audio at 4:1 PASC compression or 32 hours of MP3 audio at 12:1 MP3 compression. 80mm DVD can also be used to store more than 50 minutes of 24-bit/96kHz uncompressed digital audio or DSD (Direct Stream Digital) which features 1-bit/2.82224MHZ sampling.

Also, encoder 220 and decoder 330 can be configured to encode and decode audio data in other types of compression format such as DTS (Digital Theater Systems), ATRAC (Adaptive Transform Acoustic Coding), AAC (MPEG-2 Advanced Audio Coding), Dolby Digital AC-3, ePAC (Enhanced Perceptual Audio Coder) and VQF (Transform-domain Weighted Interleave Vector Quantization).

Parallel port 130 can also be either an EPP (Enhanced Parallel Port) or ECP (Extended Capabilities Port). Both of these parallel ports support bi-directional communication.

Other embodiments are also within the scope of the claims.

WHAT IS CLAIMED IS:

1. A hand-held optical disc apparatus comprising

a mechanism adapted to receive a CD having a maximum dimension less than 100 mm;

a reading module configured to read first compressed digital audio data stored on the CD received within the mechanism;

a decoder configured to decode the first compressed digital audio data and generate at least a portion of first uncompressed digital audio data;

a digital-to-analog converter configured to convert the first uncompressed digital audio data from the decoder to a first analog signal;

an analog output configured to receive the first analog signal;

an encoder configured to receive second uncompressed digital audio data and generate second compressed digital audio data from at least a portion of the second uncompressed digital audio data; and

a recording module configured to store the second compressed digital audio data to the CD received within the mechanism.

2. The hand-held optical disc apparatus of claim 1 wherein the CD complies with Orange Book CD standard.

3. The hand-held optical disc apparatus of claim 1 wherein the CD has a center hole having a diameter in a range of 12 mm to 18 mm.

4. The hand-held optical disc apparatus of claim 1 wherein

the CD stores first uncompressed digital audio data;

the reading module is configured to read the first uncompressed digital audio data stored on the CD; and

the digital-to-analog converter is configured to convert the first uncompressed digital audio data from the reading module to a first analog signal.

5. The hand-held optical disc apparatus of claim 1 wherein the decoder is configured to decode the first compressed digital audio data having a format

selected from a group consisting of MP3, PASC, ATRAC, DTS, AAC, AC-3, ePAC and VQF.

6. The hand-held optical disc apparatus of claim 1 wherein the reading module further comprises

a flash memory module configured to buffer and manipulate data read from the CD;

a de-modulator configured to de-modulate data stored in the CD;

a de-interleaver configured to de-interleave data stored in the CD; and

a channel decoder configured to perform error correction on data stored in the CD.

7. The hand-held optical disc apparatus of claim 1 wherein

the first compressed digital audio data and the first uncompressed digital audio data stored in the CD further includes SCMS subcode information; and

the reading module further includes a security module configured to process the SCMS subcode information,

the first compressed digital audio data and the first uncompressed digital audio data stored on the CD further including watermark information; and

the reading device further including a watermark module configured to process the watermark information.

8. The hand-held optical disc apparatus of claim 1 further comprising

an audio speaker connected to the analog output;

a first digital output configured for connection with a serial port of a computer, the first digital output being adapted to receive data either from the reading module or from the decoder, and transmit the received data to the computer;

a second digital output configured for connection with a parallel port of the computer, the second digital output being adapted to receive data either from the reading module or from the decoder, and transmit the received data to the computer; and

a third digital output which complies with S/PDIF.

9. The hand-held optical disc apparatus of claim 1 wherein the recording module is configured to receive a portion of the second uncompressed digital audio data and store the second uncompressed digital audio data on the CD.

10. The hand-held optical disc apparatus of claim 1 wherein the encoder is configured to generate the second compressed digital audio data having a format selected from a group consisting of MP3, PASC, ATRAC, DTS, AAC, AC-3, ePAC and VQF.

11. The hand-held optical disc apparatus of claim 1 wherein the recording device further comprises

a channel encoder configured to add error correction information to data to be stored in the CD;

an interleaver configured to interleave data to be stored in the CD;

a modulator configured to modulate data to be stored in the CD;

a flash memory module configured to buffer and manipulate data to be stored in the CD;

a security module configured to embed SCMS subcode information to data to be stored in the CD; and

a watermark module configured to embed watermark information to the data to be stored in the CD.

12. The hand-held optical disc apparatus of claim 1 further comprising

an analog input configured to receive a second analog signal;

an analog-to-digital converter configured to convert the second analog signal to the second uncompressed digital audio data; and

a microphone connected to the analog input.

13. The hand-held optical disc apparatus of claim 1 further comprising

a first digital input configured for connection with a serial port of a computer, the first digital input being adapted to receive data from the serial port of the computer and transmit the data either to the recording module or to the encoder;

a second digital input configured for connection with a parallel input port of the computer, the second digital output being adapted to receive data from the parallel port of the computer and transmit the data either to the recording module or to the encoder; and

a third digital input which complies with S/PDIF.

14. A hand-held optical disc apparatus comprising

a mechanism adapted to receive a DVD having a maximum dimension less than 100 mm;

a reading module configured to read first compressed digital audio data stored on the DVD received within the mechanism;

a decoder configured to decode the first compressed digital audio data and generate at least a portion of first uncompressed digital audio data;

a digital-to-analog converter configured to convert the first uncompressed digital audio data from the decoder to a first analog signal;

an analog output configured to receive the first analog signal;

an encoder configured to receive second uncompressed digital audio data and generate second compressed digital audio data from at least a portion of the second uncompressed digital audio data; and

a recording module configured to store the second compressed digital audio data to the DVD received within the mechanism.

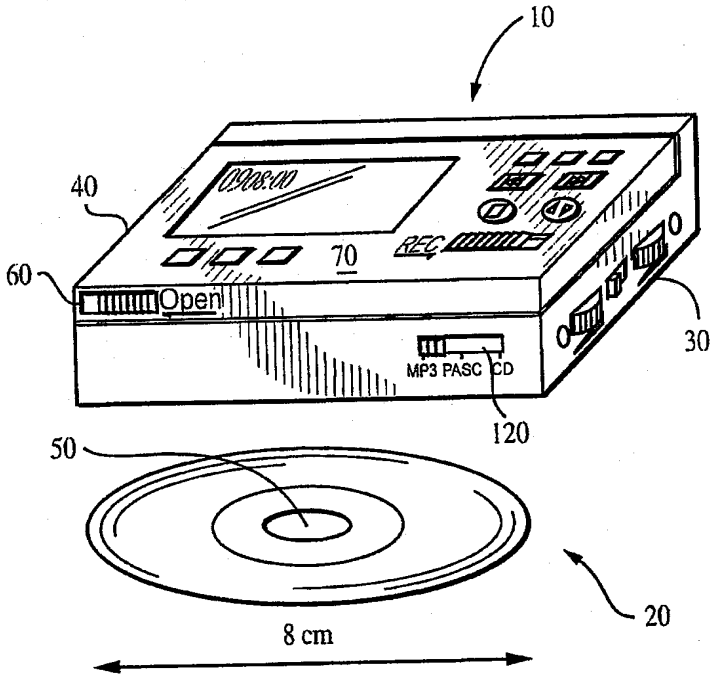

FIG. 1

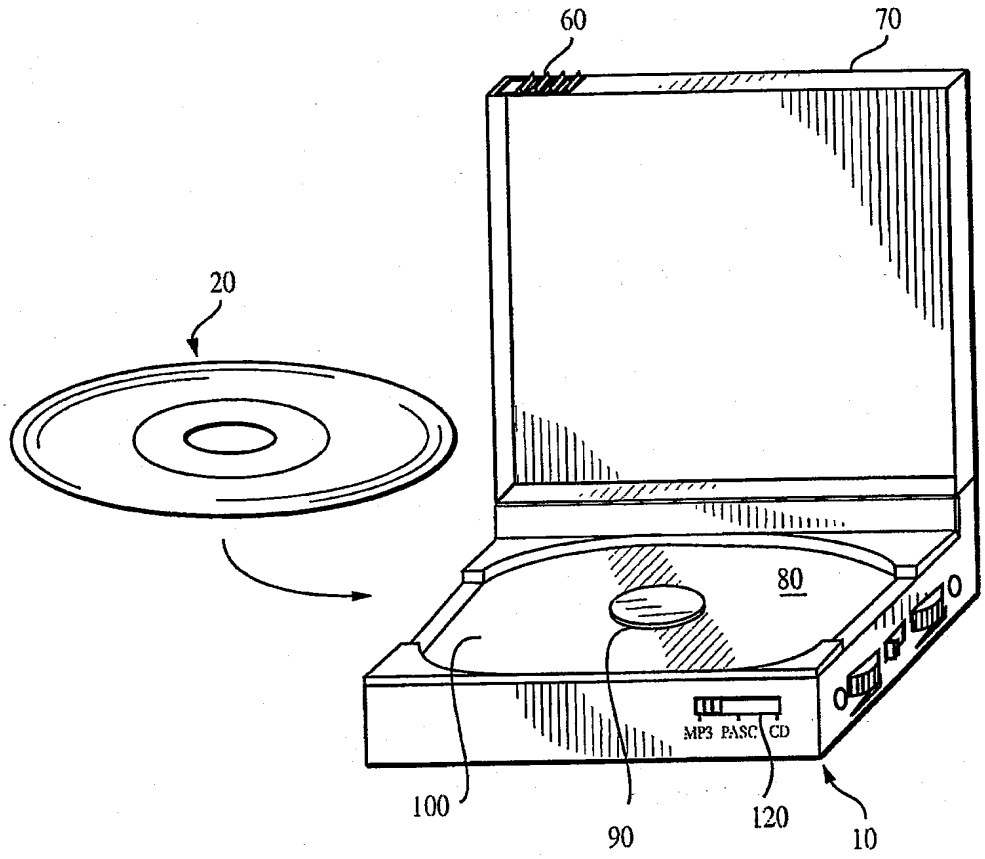

FIG. 2

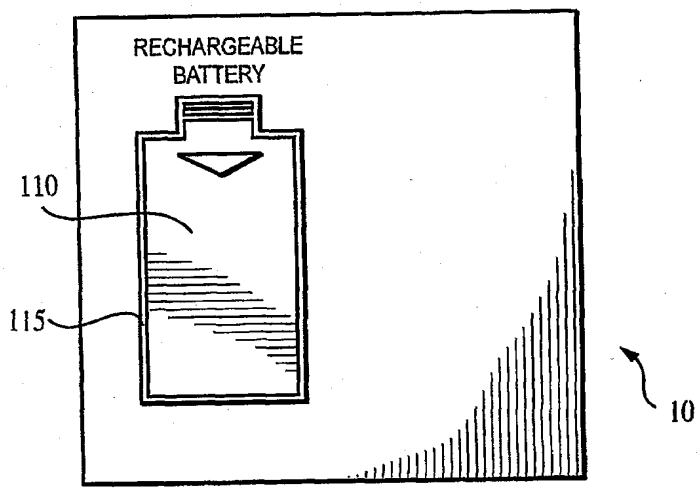

FIG. 3

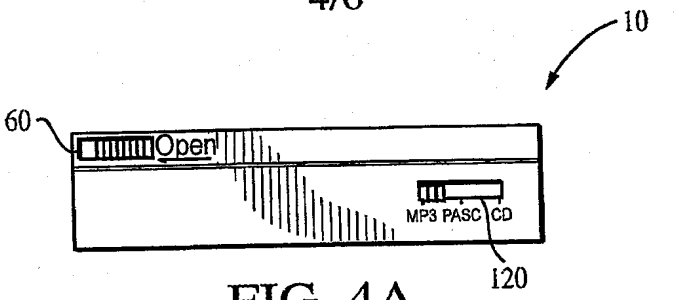

FIG. 4A

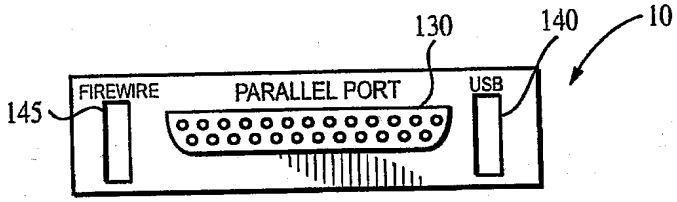

FIG. 4B

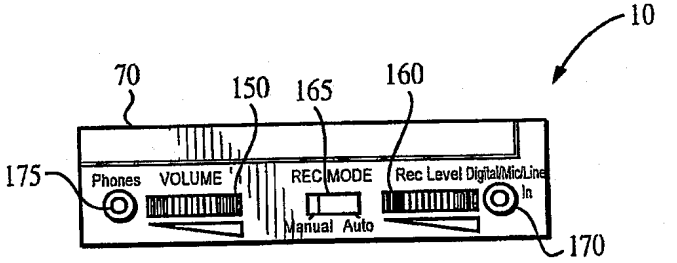

FIG. 4C

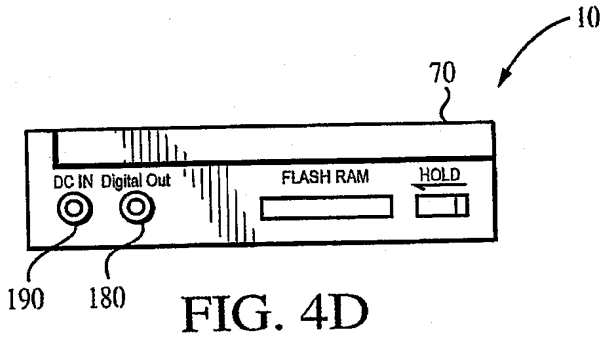

FIG. 4D

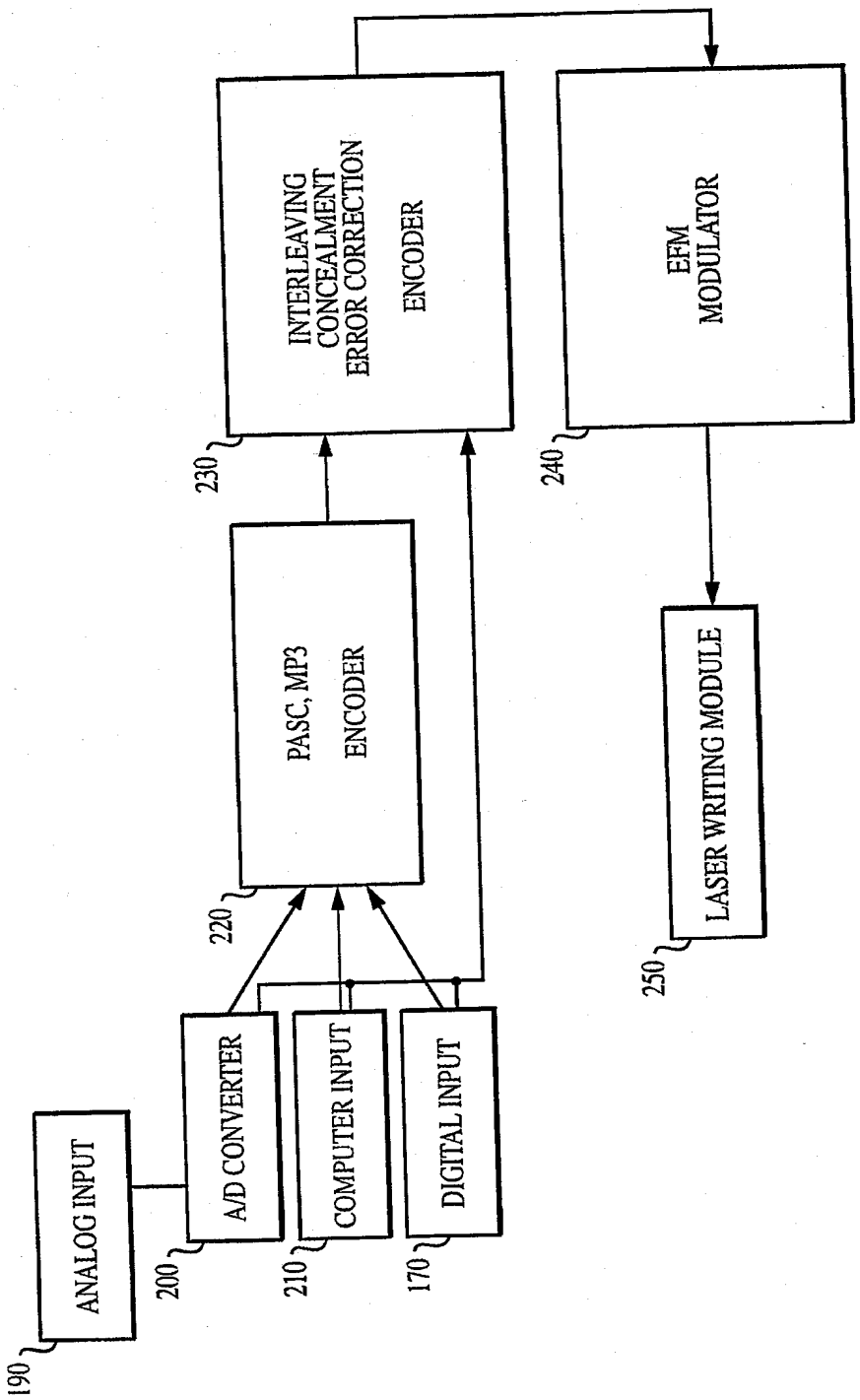
ANALOG INPUT
190
A/D CONVERTER
200
COMPUTER INPUT
210
DIGITAL INPUT
170
PASC, MP3 ENCODER
220
INTERLEAVING CONCEALMENT ERROR CORRECTION ENCODER
230
EFM MODULATOR
240
LASER WRITING MODULE
250

FIG. 5

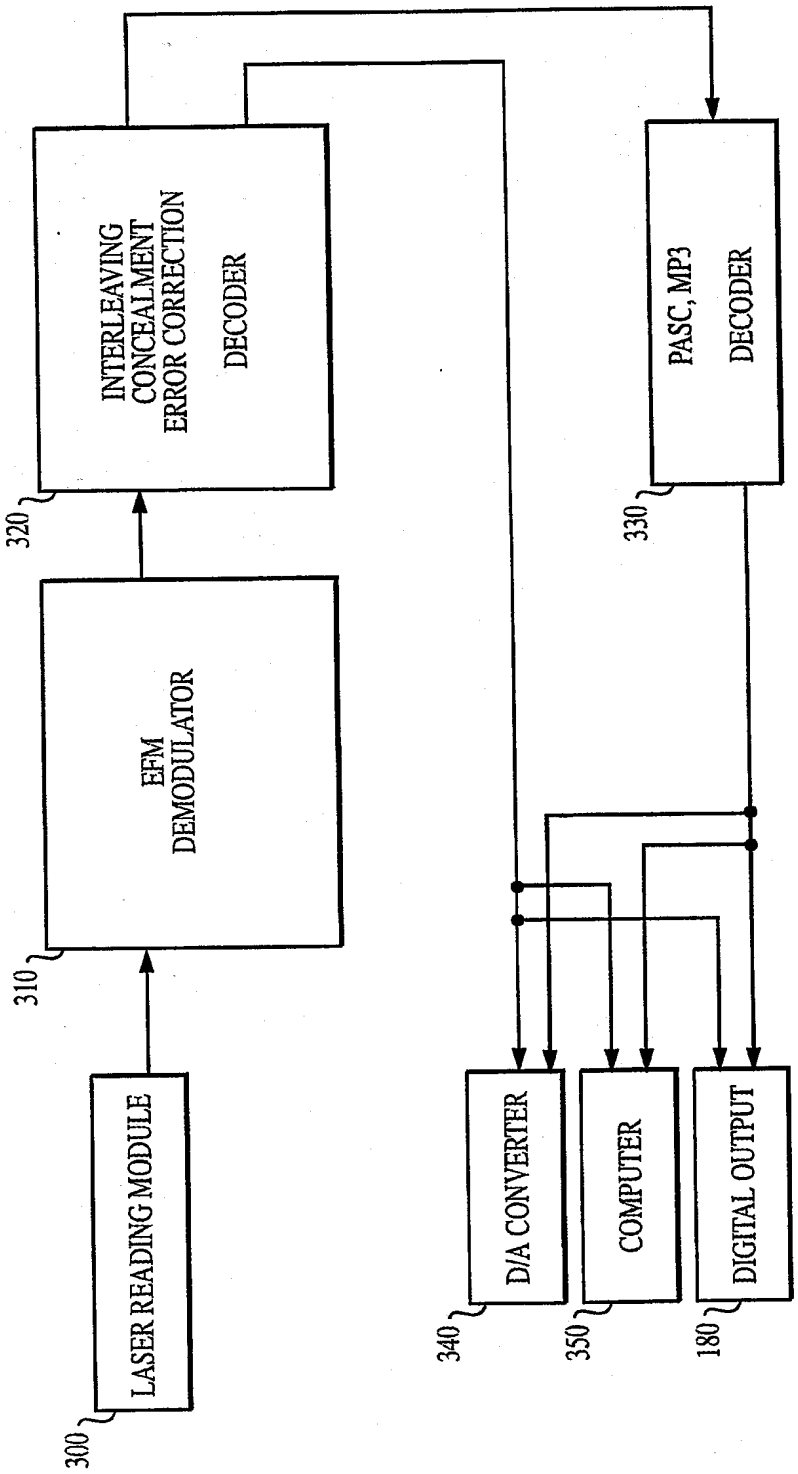
LASER READING MODULE
300
EFM DEMODULATOR
310
INTERLEAVING CONCEALMENT ERROR CORRECTION DECODER
320
PASC, MP3 DECODER
330
D/A CONVERTER
340
COMPUTER
350
DIGITAL OUTPUT
180

FIG. 6